

Porosity: A Curiosity Without Diagnostic Significance

BRUCE M. ROTHSCHILD

Arthritis Center of Northeast Ohio, Youngstown, Ohio 44512; Department of Internal Medicine, Northeast Ohio Universities College of Medicine, Rootstown, Ohio 44272

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ABSTRACT A controlled study of the relationship of two standard clinical indicators of osteoarthritis and porosity failed to demonstrate a relationship. Porosity appears to be a curiosity that has no clinical correlation and is not a sign of an identifiable rheumatologic disorder. It should be deleted as an identifier for osteoarthritis. *Am J Phys Anthropol* 104:529–533, 1997.

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Porosity of joint surfaces seen in dry bone appears to be a phenomenon that is difficult to analyze in living individuals. It does not appear to be acknowledged in standard textbooks of medical radiology (Dihlman, 1986; Ozonoff, 1992; Resnick and Niwayama, 1988; Silverman, 1985; Steinbach et al., 1975), rheumatology (Katz, 1988; Kelley et al., 1995; McCarty and Koopman, 1993; Sledge et al., 1994), orthopedics (Weinstein and Buckwalter, 1994), pathology (Anderson, 1971; Bloom and Fawcett, 1968; Gardner, 1965; Gould et al., 1964; Ham, 1974), or even in those specifically dealing with osteoarthritis (Kuetner et al., 1992; Moskovitz et al., 1984). Porosity, manifest as discontinuity of subchondral bone, has to be considered below the resolution of clinical x-rays, as radiologists have not noted it. It apparently cannot be recognized on x-ray.

As the phenomenon cannot be directly detected in life, its clinical significance can only be assumed. Several theories have been offered. Loman (1959) and Merbs (1983) suggested that porosity reflects a reaction to bone sclerosis. They suggested that the sclerotic bone loses vascularity and that the marrow becomes more fibrous, thus penetrating the subchondral bone. Sokoloff (1969), however, suggested that defects came first—that is, that intrusion of synovial fluid reached the marrow through defects in articular cartilage. Sokoloff (1969), however,

only looked at such surface defects in selected individuals with osteoarthritis. He did not suggest that such surface alterations had any diagnostic significance, nor did he test his hypothesis. The third theory simply considers porosity as exposed marrow spaces, occurring secondary to wearing away of subchondral bone (Merbs, 1983) that can occur as a complication of any form of cartilage-disrupting arthritis.

Application of these theories to skeletal analysis has been predicated on the assumption that a relationship exists between porosity and osteoarthritis (Ortner, 1968). This is an interesting hypothesis, which to my knowledge has not been subjected to rigorous assessment. The American College of Rheumatology (ACR) study group which established ACR criteria for recognition of osteoarthritis of the hip, knee, and hand (Table 1) also failed to identify any role for porosity in recognition of osteoarthritis (Altman et al., 1986, 1990, 1991).

Failure of previous studies to utilize accepted criteria for clinical/radiological recognition of osteoarthritis (Altman et al., 1986, 1990, 1991) confounded assessment of the significance of porosity. Attempts to describe anticipated skeletal manifestations of dis-

*Correspondence to: Bruce M. Rothschild, Arthritis Center of Northeast Ohio, 5500 Market Street, Youngstown, OH 44512. E-mail: bmr@neucom.edu

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TABLE 1. American College of Rheumatology (ACR) criteria for osteoarthritis

Joint	Primary identifier	Secondary identifier
Knee	Osteophytes (x-ray)	Crepitus ¹ , if bony enlargement present
Hip	Osteophytes (x-ray)	Axial space narrowing ²
Hand	Bony enlargement	None listed

¹Evidence of bone remodeling, which includes osteophytes.

²Accounts for only 2% of individuals. Crepitus is joint noise heard in some living individuals with severe arthritis but is not assessable in skeletons.

ease (Rogers, et al., 1987) have proceeded without determining whether a given condition actually existed in individuals in whom unequivocal arthritis was established in life. For example, eburnation has been erroneously (Rothschild, 1996) used as *the* major marker for osteoarthritis (Lim et al., 1995; Rogers and Dieppe, 1994). In fact, eburnation is a marker for arthritis severity (Altman et al., 1986, 1990, 1991).

Ortner's (1968) suggestion that eburnation rarely occurs without porosity would appear to suggest that porosity, like eburnation, indicates the presence of osteoarthritis. However, such a deduction is problematic. While eburnation does occur in osteoarthritis, it is not unique to osteoarthritis and does not fulfill American College of Rheumatology established criteria for recognition of osteoarthritis (Altman et al., 1986, 1990, 1991).

Conjecture has been offered (Bridges, 1991; Jurmain and Kilgore, 1995; Ortner, 1968; Waldron, 1991; Waldron and Rogers, 1991), predicated on an assumed relationship of porosity to osteoarthritis. Patterns of osteoarthritis are often utilized to assess variation in ancient life styles and patterns of work. The subsequent perceptions of association between activity and arthritis are valid only if osteoarthritis had been accurately diagnosed in the first place. If nondiagnostic characteristics were given equal weight to diagnostic criteria, one cannot know what is really being measured. As porosity and/or eburnation were considered equal in diagnostic value to standard criteria for recognition of osteoarthritis in many studies, confidence in the assessment of the impact of life style and work habits on joint surfaces appears compromised. This study subjects the assumed relationship of porosity and osteoarthritis to critical analysis.

METHODS

Identification of porosity and osteoarthritis

The knee, as a commonly reported site of porosity (Ortner 1968; Woods, 1986, 1995) and of osteoarthritis (Rothschild, 1982; Resnick and Niwayama, 1988; Woods, 1986, 1995), was chosen for assessment. Four hundred individual skeletons were selected from the Hamman Todd Collection for knee examination.

Porosity was recognized by the presence of discontinuity (pitted, disorganized lesion) of subchondral bone (Woods, 1995), in the absence of an erosive process (e.g., spondyloarthropathy-related subchondral erosions [Rothschild and Woods, 1991]). To avoid negative bias, all subchondral pitting was considered to represent porosity, independent of severity or extent.

Osteoarthritis was recognized by the presence of characteristic osteophyte formation or evidence of subchondral bone sclerosis (Altman et al., 1986, 1990, 1991; Resnick and Niwayama, 1988). These are clinical criteria (Table 1), which have also been documented as valid for assessment of defleshed skeletons (Rothschild, 1990; Rothschild and Martin, 1993). Porosity was not used as an identifier of osteoarthritis, as porosity was the characteristic being analyzed.

Eburnation was not used for diagnosis of osteoarthritis, as it is a nonspecific finding in any severe arthritis (Resnick and Niwayama, 1988). Eburnation is the result of a polishing process produced by bone rubbing on bone. Thus, eburnation identifies the location at which there was total loss of joint cartilage. This is a sign of severity of arthritis, not of the form of arthritis that caused the cartilage loss. The American College of Rheumatology (ACR) study group which established ACR criteria for recognition of osteoarthritis of the hip, knee, and hand (Table 1) also determined that there was no role for eburnation in recognition of osteoarthritis (Altman et al., 1986, 1990, 1991). Eburnation reflects the most severe form of joint space narrowing, that which occurs when all cartilage is lost. Only that amount of cartilage loss allows bone to rub on bone,

the necessary condition for occurrence of eburnation.

Joint space narrowing (not total joint space loss) can identify additional instances of osteoarthritis in individuals without osteophytes, but only for osteoarthritis of the hips, not of the knees or hands (Altman et al., 1986, 1990, 1991). Even limiting consideration to hip osteoarthritis, less than 2% of individuals with hip osteoarthritis lacked osteophytes. Even if joint space narrowing were not a very rare osteoarthritis finding in absence of osteophytes, narrowing was only a valid diagnostic criteria for osteoarthritis when accompanied by a normal erythrocyte sedimentation rate. The latter is a laboratory measure of inflammation, inaccessible in the nonliving individual. Narrowing, by itself, is a nonspecific finding.

No attempt is made to address the concept of severity. Correlation between disability, clinical findings, and radiologic evidence of disease is problematic. Individuals with total absence of joint cartilage (bone on bone or eburnation) often have no pain or limitations, while those with only minimal joint space narrowing may be severely disabled. It is unclear that osteoarthritis-related disability can be truly assessed by examination of skeletons or radiographs.

The presence of calcium pyrophosphate deposition disease was also determined, as it is sometimes confused/misclassified with osteoarthritis (Rothschild and Martin, 1993). Calcium pyrophosphate deposition disease (CPPD) was recognized if a calcified sheet reflecting onto the articular surface was present (Genant, 1976; Markel and Hart, 1982; Resnick and Niwayama, 1988; Rothschild, 1982; Rothschild and Thillaud, 1991).

Statistical analysis

The association between porosity and osteoarthritis was tested with a 2×2 Chi-square analysis. Yates's correction was applied. The Student *t*-test was used to determine differences in average age of individuals with porosity and osteoarthritis. Chi-square was also used to determine whether there was association between age cohorts, race, or sex and either porosity or osteoarthritis. The possible effect of age on porosity was also tested with Chi-square.

TABLE 2. Demographics of porosity and of osteoarthritis of the knee in the Todd Collection¹

	Porosity	Osteoarthritis
Number of Individuals	70	118
Average Age (years)	50	54
Age distribution		
<35	7	8
35-44	17	25
45-54	21	29
55-64	9	23
65-74	12	23
>75	4	10
Race/sex distribution		
Caucasian male	39	72
Caucasian female	4	7
Black male	22	24
Black female	5	15

¹Four hundred skeletons were examined for the presence of porosity and/or osteoarthritis. Both conditions were present in 21. Neither condition was seen in 233.

RESULTS

Knee porosity was found in 70 of 400 skeletons (17.5%) in the Hamman Todd Collection, while osteoarthritis was present in 118 (29.5%). Both phenomena coexisted in only 21 individuals (5%). Two hundred and thirty-three individuals (58%) had neither porosity nor osteoarthritis. Forty-nine (70%) of the individuals with porosity had no evidence of osteoarthritis. Ninety-seven individuals (82%) with osteoarthritis lacked porosity.

No significant relationship exists between porosity and osteoarthritis (Chi square = 0.48, 1 d.f., $P > 0.50$, nonsignificant). No confounding factors could be identified to explain the lack of relationship between porosity and osteoarthritis. The average age (Table 2) of individuals with either porosity or osteoarthritis was indistinguishable (*t*-test = 0.374, 1 d.f., $P > 0.5$). Analysis of porosity and increasing age, when age was grouped into 10 year intervals (Table 2), was also statistically nonsignificant (Chi square = 2.49, 5 d.f., $P > 0.70$). No significant difference (Table 2) was found by sex (Chi square = 1.068, 1 d.f., $P > 0.25$) or by race (Chi square = 0.588, 1 d.f., $P > 0.4$) between individuals with and without porosity or with and without osteoarthritis.

Porosity was also not influenced by the presence of calcium pyrophosphate deposition disease (CPPD). While 22 instances of CPPD of the knee (Rothschild and Thillaud, 1991; Rothschild et al., 1992) were noted in

this series, only two had associated porosity. Collapse of the tibial plateau was noted in four individuals, and porosity was not observed in those cases either.

DISCUSSION

No relationship could be demonstrated between porosity and osteoarthritis, CPPD, or even such severe structural perturbations as collapse of the tibial plateau. Porosity is a phenomenon involving subchondral bone. Woods (1995; p. 18) described the subchondral bony plate as a "thin unvascularized layer of bone subjacent to the articular cartilage and lying over the cancellous bone of the epiphysis." He further noted that eburnated (osteoarthritic) bone was smooth, glistening, and nonporous. Eburnation and porosity are unrelated. Even if one accepts eburnation as a sign of osteoarthritis, there is still no correlation with porosity. Ortner's (1968) suggestion/hypothesis was not sustained by Woods's (1986, 1995) studies, just as the hypothesized relationship between porosity and osteoarthritis (when measured by the ACR criteria emphasizing osteophytes) was not confirmed in my analysis. Woods (1995) further demonstrated that porosity does not correlate with arthritis severity, as measured by eburnation, though he defines eburnation as a bone rubbing on bone phenomenon, given its localization to weight-bearing joint regions. However, he showed that porosity was essentially a phenomenon of noncontact and therefore non-weight-bearing areas, which led Woods to postulate that porosity may actually reflect a defect in local cartilage/bone nutrition.

Porosity remains an macroscopic curiosity that has no identifiable clinical correlation and is therefore not a sign of any identifiable rheumatologic disorder. It should be deleted as an identifier of osteoarthritis.

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